

## PATENT ABSTRACTS OF JAPAN

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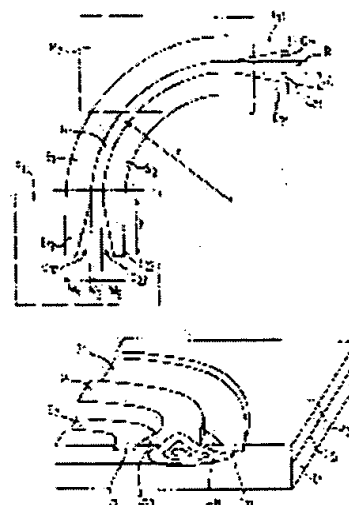
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### (54) SEMICONDUCTOR DEVICE AND ITS PRODUCTION

(57)Abstract:

PURPOSE: To lessen the loss of light beams by providing the curvilinear part of a light guide with means for limiting light into the light guide.

CONSTITUTION: The curvilinear part of the light guide G is provided with the means for limiting the light into the light guide G. The means include a waveguide structural body having a waveguide layer CG and a fine line R in a relief form which projects from this waveguide layer CG and determines the optical path to be traced by the light as well as groove structural bodies S1, S2. The depth of these structural bodies S1, S2 is fixed and the central part is a curvilinear part which exactly follows up the edge of the fine line R. The ends thereof are the beginning end and terminating end of the curvilinear part and part from the edges of the fine line R. The bottoms of the structural bodies S1, S2 exist in the waveguide layer CG in the position not reaching the lower part of the waveguide layer. As a result, the integrated light guide which is low in the loss in both of the curvilinear part and



the straight part is obtd.

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## Patent &amp; Utility Model Concordance



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CLAIMS DETAILED DESCRIPTION TECHNICAL FIELD PRIOR ART TECHNICAL PROBLEM  
MEANS DESCRIPTION OF DRAWINGS DRAWINGS

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[Translation done.]

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**CLAIMS**


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[Claim(s)]

[Claim 1] It is the semiconductor device concerned which is a semiconductor device which is characterized by providing the following, and which is equipped with the integration light guide which has one bay and one bend at least, and the aforementioned light guide has a means to restrict light into a light guide by the part for an aforementioned bend, and includes the slot established in these meanses along the marginal part of a light guide in the aforementioned field for a bend. The aforementioned means is a waveguide further. Thin \*\* of the letter of relief which determines the optical path to which it projects from this waveguide and light follows the inside of this waveguide.

[Claim 2] The semiconductor device characterized by preparing the slot of the same structure as the both sides of a light guide by the part for an aforementioned bend in a semiconductor device according to claim 1.

[Claim 3] The semiconductor device with which the edge of a slot is characterized by having estranged only the angle of 2 degrees - 5 degrees from above thin \*\* in a semiconductor device according to claim 1 or 2.

[Claim 4] The semiconductor device characterized by the aforementioned angle being 3 degrees in a semiconductor device according to claim 3.

[Claim 5] The semiconductor device characterized by the aforementioned angle being 4 degrees in a semiconductor device according to claim 3.

[Claim 6] The semiconductor device characterized by there being less depth of flute in the thickness direction of the aforementioned waveguide than 20% of the thickness of this waveguide in a semiconductor device given in any 1 term of claims 1-5.

[Claim 7] It is the semiconductor device which it is the thing of the mold with which the structure of a light guide has two-layer, and a waveguide is formed in the front face of the limit layer of a low refractive index in a semiconductor device given in any 1 term of claims 1-6, and is characterized by carrying out \*\*\*\*\* formation of the above thin \*\* in the same material as this waveguide on the surface of a waveguide.

[Claim 8] It is the semiconductor device characterized by for the structure of the light guide which has two-layer being a gay structured type in a semiconductor device according to claim 7, and for a limit layer consisting of the III-V group material of a conductivity type predetermined with the 1st specific resistance value, and forming it on the substrate of III-V group material, and for a waveguide consisting of the same conductivity type as a limit layer, and the same III-V group material with the 2nd specific resistance value, and being formed on the aforementioned limit layer.

[Claim 9] The semiconductor device characterized by for the limit layer consisting of n+ type InP, for the waveguide consisting of n- type InP in the semiconductor device according to claim 8, and the substrate consisting of InP of half-insulation.

[Claim 10] It is the semiconductor device characterized by being the thing of the mold with which the structure of a light guide has three layers in a semiconductor device given in any 1 term of claims 1-6, forming a waveguide between two limit layers of a low refractive index, and above thin \*\* consisting of

the material of an upper limit layer.

[Claim 11] It is the semiconductor device characterized by for the structure of the light guide which has three layers being a hetero structured type in a semiconductor device according to claim 10, for two limit layers consisting of the III-V group material of two components, for a waveguide consisting of three components or 4 component III-V group material, and the substrate consisting of 2 component III-V group material.

[Claim 12] It is the semiconductor device characterized by for a limit layer consisting of InP in a semiconductor device according to claim 11, and the waveguide consisting of GaInAsP formed on the substrate of InP of half-insulation.

[Claim 13] In \*\*\*\*\* of claims 1-12, or a semiconductor device given in the first term, the thickness of a waveguide is about 1.5 micrometers. When a limit layer exists, this limit layer thickness is about 0.25 micrometers. It is the semiconductor device characterized by the slot having the depth to which the pars basilaris ossis occipitalis is located in about 0.2 micrometers from the top side of a waveguide by above thin \*\* carrying out the letter of relief which has the thickness of about 0.75 micrometers, and the longitudinal direction size of about 4 micrometers.

[Claim 14] In manufacturing the semiconductor device of a publication in any 1 term of claims 1-6 The following processes, i.e., the structure of at least two semiconductor-material layers of aIII-V group, are formed at least. It has a low refractive index for a lower layer (11 12) constituting a limit layer (C1). The process which penetrates the radiation which has the wavelength  $\lambda$  for operating a semiconductor device, and constitutes a waveguide (CG) while the layer (12 21) which covers the layer of this bottom has a high refractive index, b) Width of face forms [ height ] thin \*\* (R) which has a part for a bend in the shape of relief by WG by h on the aforementioned waveguide (CG). This thin \*\* (R) is a process made into the thing for restricting a waveguide into the layer (CG) of the bottom. this process The system of the mask (M1, M2) of the 1st kind which covers only the field of thin \*\* (R) is used. Cover depth h in the surrounding semiconductor region of the system of this mask by the gas which performs selective etching to the system of this mask following this, and the so-called reactive ion etching is performed. The process concerned from which it obtains it by this as the waveguide of the above thin \*\* (R) bottom has thickness eG, c) Two slots (S1.S2) which have depth [ in the aforementioned waveguide (CG) ] P and width of face WS on both sides for a bend of above thin \*\* (G) are formed in the front face of the equipment obtained by this. It is the process which only an angle  $\alpha$  makes estrange these slots from above thin \*\* at the aforementioned edge for a bend, and restricts light to a longitudinal direction in a waveguide (CG). this process The system of the mask (M3) of the 2nd kind which has the aperture (O1, O2) which is in agreement with the field of the aforementioned slot (S1.S2) is used. Distance d of these apertures on above thin \*\* (R) is made into  $0 < d < WG$ . The semiconductor region in an aperture (O1, O2) by performing the so-called reactive ion etching until etching depth P in the waveguide (CG) which has thickness eG following this becomes a certain depth of eG shallower than 20% The manufacture method of the semiconductor device characterized by performing the process concerned to acquire one by one.

[Claim 15] The manufacture method of the semiconductor device characterized by forming the two-layer (11 12) gay structure of a III-V group's material at the aforementioned process a in the manufacture method of a semiconductor device according to claim 14.

[Claim 16] The manufacture method of the semiconductor device characterized by forming above thin \*\* (R) into the material of the 2nd layer (12) of gay structure at the aforementioned process b in the manufacture method of a semiconductor device according to claim 15.

[Claim 17] It is the manufacture method of the feature and \*\*\*\*\* about carrying out \*\*\*\*\* composition of the substrate (10) of InP of n+ conductivity type by which the layer of InP of n-conductivity type is formed upwards of epitaxial growth in two-layer gay structure in the manufacture method of a semiconductor device according to claim 16.

[Claim 18] In the manufacture method of a semiconductor device according to claim 17 two-layer gay structure The 1st epitaxial layer of InP of n+ conductivity type (11), The manufacture method of the semiconductor device characterized by carrying out \*\*\*\*\* composition of the 1st epitaxial layer (11)

of InP of n<sup>+</sup> conductivity type arranged on the front face of the solid-state single crystal half insulation substrate (10) of InP, and the top layer (12) of InP of n-conductivity type arranged in this 1st epitaxial layer.

[Claim 19] The manufacture method of the semiconductor device characterized by forming two-layer [ two-layer / of a III-V group's material / and ] (21), i.e., the 1st lower layer, and the upper hetero structure of the 2nd layer (22) at the aforementioned process a in the manufacture method of a semiconductor device according to claim 14.

[Claim 20] The manufacture method of the semiconductor device characterized by forming above thin \*\* (R) at the aforementioned process b into the top layer of two-layer hetero structure, i.e., the material of the 2nd layer (22), in the manufacture method of a semiconductor device according to claim 19.

[Claim 21] The manufacture method of the semiconductor device characterized by carrying out \*\*\*\*\* composition of the 3rd layer (23) which has arranged double hetero structure on the front face of the aforementioned layer (21 22) at the aforementioned process a in the manufacture method of a semiconductor device according to claim 19, making this refractive index of the 3rd layer lower than the aforementioned refractive index of the 2nd layer (22), and making this 2nd layer (22) into a waveguide (CG).

[Claim 22] The manufacture method of the semiconductor device characterized by forming above thin \*\* (R) in the 3rd aforementioned layer (23) at the aforementioned process b in the manufacture method of a semiconductor device according to claim 21.

[Claim 23] In the manufacture method of a semiconductor device given in any 1 term of claims 19-22 The 1st layer (21) is used as the 2 component epitaxial layer of InP of n-conductivity type with aforementioned hetero structure or aforementioned double hetero structure (21, 22, or 21, 22, 23). Use the 2nd layer (22) as the 4 component epitaxial layer of GaInAsP, and when the 3rd layer (23) exists, this 3rd layer is used as the 2 component epitaxial layer of InP of n-conductivity type. The manufacture method of the semiconductor device characterized by arranging this sequential layer on the solid-state substrate of InP of single crystal half insulation.

[Claim 24] In the manufacture method of a semiconductor device according to claim 17, 18, or 23 It considers as n<sup>+</sup> conductivity type by doping s<sup>+</sup> ion by the concentration of 4-10<sup>18</sup>, while making InP material into n-conductivity type only by the background doping. When the solid-state substrate of InP of half-insulation exists, this solid-state substrate is obtained by the raising method by the Czochralski method which used encapsulation of about 14.1016 concentration. An epitaxial layer is the manufacture method of the semiconductor device equipment characterized by obtaining by one of the MOVPE or VPE type methods.

[Claim 25] It sets to the manufacture method of a semiconductor device given in any 1 term of claims 14-24, and is 0.5 micrometer < h < 0.75 micrometer. 20% of WG\*\*4micromP < eG WS=1-4micrometer 1.5 micrometer < eG < 2.5 micrometer The manufacture method of the semiconductor device characterized by considering as 2 degrees < alpha < 5 degrees.

[Claim 26] The manufacture method of the semiconductor device characterized by carrying out \*\*\*\*\* composition of the superposition layer of the layer (31) of a silica (SiO<sub>2</sub>), and the layer (32) of a photoresist for the system of the mask of the 1st kind in the manufacture method of a semiconductor device given in any 1 term of claims 14-25.

[Claim 27] In the manufacture method of a semiconductor device according to claim 26, thickness of the layer (31) of a silica is set to about 500-700nm at the aforementioned process b. Set the layer (32) of a photoresist to about 0.7-1 micrometer, and are after the deposition and the layer of the aforementioned silica is heated for 30 minutes at 400 degrees C before deposition of the layer of the aforementioned photoresist. The layer (32) of the aforementioned photoresist is heated for about 30 minutes at the temperature of about 90 degrees C after the deposition. A photolithography processes of the layer (32) of a photoresist prescribe above thin \*\* (R). This forms a mask (M2) and the layer (32) of a photoresist is gradually heated at 180 degrees C following this. Next, it \*\*\*\*\*s around the aforementioned mask (M2) by reactive ion etching using CHF<sub>3</sub> gas until the top side of the top layer of a semiconductor material exposes the layer (31) of a silica (SiO<sub>2</sub>). The manufacture method of the semiconductor device



characterized by this forming a mask (M1) in the aforementioned mask (M2) bottom.

[Claim 28] It is the manufacture method of the semiconductor device characterized by forming by \*\*\*\*\*ing a semiconductor layer around the system of the mask (M1, M2) of the 1st kind by the mixed gas in which above thin \*\* (R) contains CH<sub>4</sub>/H<sub>2</sub> gas at least in the manufacture method of a semiconductor device according to claim 27.

[Claim 29] The manufacture method of the semiconductor device characterized by carrying out \*\*\*\*\* composition of the photoresist layer (33) whose thickness is 2-4 micrometers about the system of the mask of the 2nd aforementioned kind in the manufacture method of a semiconductor device given in any 1 term of claims 26-28.

[Claim 30] In the manufacture method of a semiconductor device according to claim 29, the aforementioned aperture (O1, O2) is formed in a photoresist layer (33) according to the process of a known RINGURA fee at the aforementioned process c. This forms the mask (M3) of the 2nd kind. the posterior canal (S1, S2) The semiconductor layer exposed in the aperture (O1, O2) until etching depth P was obtained in the waveguide (CG) is formed by \*\*\*\*\*ing. The mixed gas which contains CH<sub>4</sub>/H<sub>2</sub> gas at least performs this etching process, and two systems (M1, M2, and M3) of a mask are related with a photoresist. in an acetone The manufacture method of the semiconductor device characterized by removing by decomposing in hydrogen fluoride (HF) about a silica (SiO<sub>2</sub>).

[Claim 31] The manufacture method of the semiconductor device characterized by forming the aforementioned aperture (O1 and O2) during formation of the mask (M3) of the 2nd aforementioned kind in the manufacture method of a semiconductor device according to claim 30 so that only a distance  $d < WG$  may be estranged mutually in the upper part of thin \*\* (R) where these are still covered with the system of the mask (M1, M2) of the 1st kind.

[Claim 32] In the manufacture method of a semiconductor device according to claim 30 the aforementioned aperture (O1, O2) during formation of the mask (M3) of the 2nd kind It forms so that it may be combined mutually in the upper part of thin \*\* (R) still covered and these may constitute one aperture by the system of the mask (M1, M2) of the 1st kind. This one aperture is the manufacture method of the semiconductor device which is each edge of this aperture that forms the edge of a slot (S1, S2), and is characterized by making it have the following configuration.

[Claim 33] The manufacture method of the semiconductor device characterized by covering a length of about 50 micrometers, and only for an angle alpha making the edge of the aforementioned aperture (O1, O2) estrange from above thin \*\* (R) in the manufacture method of \*\*\*\*\* given in any 1 term of claims 30-32, and forming the edge (E11, E12, E21, and E22) of a slot (S1, S2).

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**DETAILED DESCRIPTION**

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[Detailed Description of the Invention]

(Field of the Invention)

this invention is a semiconductor device equipped with the integration light guide which has one bay and one bend at least, and the aforementioned light guide has a means to restrict light during a guide by the part for an aforementioned bend, and it relates to the semiconductor device concerned which includes the slot prepared along the marginal part of a light guide in the aforementioned field for a bend in these meanses.

this invention relates to the method of manufacturing still such a semiconductor device.

this invention is equipped with the light guide which has various curvatures, and is used for manufacture of the Mach-TSUENDA (Mach-Zehnder) modulator in which each light guide has a part for a part for a bay, and a bend one by one, or integration optical equipment like an optical switch.

(Prior art)

It is known from the paper "Probleme der Topographie Integriet Schaltungen" written by [ of a book "2213-Frequenz Vol.35 (1981), September No.9 Berlin-Dentschland" / in the 248th page ] Mr. [ Carl Heinz tea TOGEN (Karl-Heinz TIETGEN) ] to manufacture the pad light guide which has a part for a bend.

\*\*\*\*\* composition of this pad light guide is carried out in thin \*\* which has an only bigger refractive index than the refractive index of a substrate, and this thin \*\* has been obtained by pouring in titanium into the substrate of  $\text{LiNbO}_3$ , therefore this thin \*\* is in one level which is in agreement with the bottom flat side of a substrate. In such a light guide embedded completely, loss always increases.

In order to reduce loss by the direction dispersion of a path by part for the bend of a light guide, in the above-mentioned paper, forming a slot, for example by etching, embedding in the same height as a part for this bend with radius of curvature with this bigger slot than the part for an aforementioned bend, and following the marginal part of a light guide correctly is proposed. The slot by this etching enlarges a difference of the refractive index between the atmosphere which is in the exterior of a light guide by the marginal part side of the light guide of the direction which has the radius of curvature of the larger one, and this light guide.

The radius of curvature of about 0.5mm can be obtained by this method by this paper, and it is made for this not to exceed 3dB for loss.

When such a curved light guide is manufactured, loss arises by dispersion by the marginal part of a light guide being uneven to an external atmosphere, and it is also indicated by this paper that these losses need to take into consideration the problem relevant to this, for example, reflection, the direction radiation of a path, and mode transformation if the difference of a refractive index becomes large.

In order to make these problems decrease, the light guide which the slot formed of etching has a part for the pars basilaris ossis occipitalis which inclines slightly and goes up towards the top side of a substrate at the edge of this slot that is in agreement with the start edge of a portion and termination to which the light guide curved, therefore was embedded is regulated by only the substrate of the low refractive index in a part for a bay in the longitudinal direction.

On the other hand, the optical loss by the radiation in the curved light guide is taken into consideration and explained by the reference of "Marcatili and Miller" in "BellSyst.Techn.48 and 2161(1969)."

If the wave of light reaches a part for the bend of a light guide, it is necessary to fit this wave to a part for this bend. A part of energy transmitted for this purpose is changed into a radiation mode. Therefore, energy is emitted to a waveguide side in distribution.

These losses by radiation are based on the fact that it is necessary to move electromagnetic field at a speed quicker than the speed of the light in atmosphere, in order to obtain the same phase velocity as the exterior by part for a bend. While maintaining the wave front, in order to actually move according to a wave front with a fixed angular velocity, it is necessary to proportion the phase velocity of a tangential direction in the distance between the point taken into consideration and the center of curvature of a light guide. If a certain distance D measured from the radial border of thin \*\* which constitutes a light guide is exceeded, it will become later than the phase velocity needed for velocity of propagation maintaining the wave front. Therefore, from this distance, the mode will not be able to be spread any longer, but light will be emitted into the substrate located in the height of a curve.

The conversion to the radiation mode of a trapped mode is very disadvantageous for these monochrome mode light guides, when it has the radius of curvature of length with an inadequate monochrome mode light guide.

The formula of a book "Topics in Applied Physics-Vol.7" which is indicated by the page [ 133rd ] chapter "Integrated Optics" and was established by Mr. mull KATIRI (Marcatili) has given the criticality-radius of curvature r more as a function of the longitudinal direction limit distance D lambda in the mode, i.e., the wavelength used for accuracy as a function of the longitudinal direction range of disappearance of a wave.

Radiation loss cannot be disregarded any longer, when the radius of curvature of a light guide satisfies the following inequalities.

$r < 24\pi D^3 / \lambda^2$  -- the radius of curvature of a light guide can be made small, without according to this formula, the more increasing the loss produced in the direction of the exterior of a curve, the more longitudinal direction limit distance increases

In the case of a monochrome mode light guide, it is drawn from this formula that a criticality-radius is about 10mm. Consequently, when radius of curvature is smaller than 20mm, the loss by radiation changes good and begins to become large.

According to this formula, it is drawn that it is necessary to increase the longitudinal direction limit distance in the position level of the bend of a light guide, and this is completely in agreement with the indication in the book indicated first.

However, according to the book indicated to the beginning which shows the conventional technology, this problem is difficult to solve to a monochrome mode light guide for the fact of increasing as soon as the difference of the refractive index of loss by dispersion and the atmosphere comparatively for a limit of mode transformation becomes large.

(Object of the Invention)

therefore, the radius of curvature in the book which mentioned the technical problem above -- writing -- <TXF FR=0001 HE=250 WI=080 LX=0200 LY=0300> -- it has a part for the bend of radius of curvature smaller than 500 micrometers typically, and the \*\*\*\*\* thing for which a very small integration light guide smaller than especially 1 dB/cm is manufactured has loss in the both sides for a part for a bend, and a bay

Without making dispersion or loss by mode transformation increase, these technical problems are solved by means of this invention to restrict a part for the bend of a light guide so that radiation loss may be oppressed, and they apply these meanses to thin \*\*\*\*\* structure with very less loss in itself than known completeness pad type light-guide structure from the former further.

(The means for solving a technical problem)

this invention is a semiconductor device equipped with the integration light guide which has one bay and one bend at least. In the semiconductor device concerned which the aforementioned light guide has a means to restrict light into a light guide by the part for an aforementioned bend, and includes the slot

prepared along the marginal part of a light guide in the aforementioned field for a bend in these meanses. The aforementioned means also contains the waveguide structure which has further a waveguide and thin \*\* of the letter of relief which determines the optical path to which it projects from this waveguide and light follows the inside of this waveguide. The aforementioned means contains the slot structure further and the depth of this slot structure is fixed. The center section of this slot structure follows the marginal part of above thin \*\* correctly by the part for an aforementioned bend. The edge of this slot structure is estranged from the marginal part of above thin \*\* at the aforementioned start edge and aforementioned end edge for a bend, and it is characterized by locating the pars basilaris ossis occipitalis of this slot structure in this waveguide in the level position which does not reach the bottom portion of the aforementioned waveguide.

It explains per drawing below.

the -- when 1a view has a certain distance D measured from the outside convex edge of this light guide in curved light-guide (waveguide) G which has radius of curvature r and this distance D exceeds this distance, it is the distance D which becomes later than a phase velocity required for velocity of propagation to maintain the pars basilaris ossis occipitalis (slash field) of a wave. Therefore, from this distance, light will be emitted into a substrate. this -- the -- it is shown in 1b view the [ this ] -- 1b view shows the optical path of the light beam in curved light-guide G which has not established the limit (regulation -- namely, -- shutting up) means by this invention from the upper part. It progresses straightly, especially it is divided, therefore, as for the course of an optical path, light shows [ \*\*\*\* in a substrate 10 in all the energy of a trapped mode ] that one main lobe and some minor lobes are formed. the -- the zone which shows the zone shown in 1b view with a dense point by \*\*\*\*\* to a high energy corresponds to low energy. Light progresses in the direction of an arrow. the -- if 1b view exceeds a part for the bend of a light guide, in light-guide G shown by the dotted line, it is already shown that energy does not remain.

on the other hand -- the -- 1c view shows the optical path of the light beam in curve light-guide G which established the limit means by this invention from the upper part. Even if all the energy of a trapped mode exceeds a part for the bend of a light guide, actually remaining in the light guide is shown. Light is spread in the direction of an arrow.

However, when applying the conventional technology which forms a slot by etching along the marginal part of a light guide in the height, a light guide serves as a multimode from a horizontal viewpoint, and it is necessary to make it the difference of the effective refractive index between a waveguide field and the limit field of the contiguity not exceed the order of 10<sup>-2</sup>. Furthermore, loss by distribution is introduced for the diffraction you are made to produce by the irregularity of the side. According to this invention, the problem mentioned above with the equipment seen and shown in a view 2 from the upper part is solved.

This equipment has light-guide G to which the front face was restricted by thin \*\* R which has at least one bend which has the average radius r, and bay. Furthermore, this equipment has the means which maintains the path of a light wave by light-guide G.

The slots S1 and S2 prepared along the marginal part of this light guide by the bend of a light guide are included in these meanses. According to this invention, these depth of flute presupposes that it is fixed to other datum level, for example, a substrate, as opposed to the top side of this equipment. \*\* which has the longitudinal direction size WS with these slots fixed in the bend of a light guide, The longitudinal direction size of the edges E11 and E12 to a slot S1 and the edges E21 and E22 to a slot S2 is gradually decreased as it approaches the edge of a slot. The radial-border section of a slot is kept parallel to the marginal part of a light guide, and the marginal part of the slot of the direction near the marginal part of a light guide leaves the strips Q11 and Q21 which form the corner which is made to dissociate from the marginal part of a light guide, and has an angle alpha among these, and Q12 and Q22. Edges E11, E21, E12, and E22 are made to extend on both sides of the edge of the bend of a light guide at length l. these meanses -- the perspective diagram of the 3rd and 4 view -- or as shown in the cross section of the 5a, 5b, and 5c view, \*\*\*\*\* composition of at least two layers C1 and CG is carried out, and the light guide also includes the fact that thin \*\* R is formed in relief on Layer CG.

A layer C1 is a limit layer which has a low refractive index from the layer CG which covers this layer. Layer CG is a waveguide, i.e., the layer which a wave spreads. Thin \*\* R formed in the front face of this waveguide restricts the optical path which a wave follows in a waveguide.

As for this thin \*\* R, it is desirable to make it larger than height h which chose the longitudinal direction size WG on equipment.

Under these conditions, mode transformation can be avoided by two having-two-incomes meanses.

Shortly after a light guide serves as a straight line, a slot depends one having-two-incomes means on the fact of swerving only from an angle alpha, from a waveguide field, and the having-two-incomes means of another side is based on the fact of being prepared in the portion P which generally does not exceed 20% of the thickness eG of Waveguide CG, without continuing and establishing a slot in the whole thickness of Waveguide CG.

This rate is calculated as relation between the refractive index of material, and the wavelength transmitted, in order to restrict a beam by part for the bend of a light guide or to lose mode transformation. Therefore, the means by this invention, i.e., a means to arrange light-gage waveguide thin \*\* which has a part for a bend on - waveguide, - The slot means established to the marginal part of waveguide thin \*\* in a part for a bend, a means to begin the slot on these from the edge for a bend, and to make only an angle alpha estrange from the marginal part of waveguide thin \*\*, By using a means to form the slot on these in the depth shallower than the thickness of a waveguide, - Loss of a beam The fact that there is no lateral dispersion is benefited very small in a part for a bay. to b \*\*\*\* this beam Horizontal combination can be easily carried out now at other beams with which a wave spreads the inside of the same waveguide. c) In a part for a bend, loss of this beam becomes very small and the radius of curvature for this bend can do it very small at about 50 micrometers. d) Since it does not reach the pars basilaris ossis occipitalis of a waveguide, a slot can avoid any mode transformation, and since it is comparatively shallow, the loss of e depth of flute resulting from longitudinal direction dispersion by the diffraction on a wall decreases extremely.

Therefore, the performance of the equipment which provided the means by this invention becomes high especially.

Example I: The 3rd, 4, and 5 views show one example of the equipment which has the integration light guide (waveguide) which established the means by this invention.

This light-guide structure is n arranged on n+ the limit layer C1 which has the low refractive index which consists of InP of type and this layer C1 which can be formed for example, on the half-insulating substrate 10 of InP. - It is gay structure with thin \*\* R of the thin meat which consists of the same material as the waveguide CG which consists of InP of type, and this layer CG.

In order to acquire the above-mentioned gay structure, other 2 component material of the III-V group from whom specific resistance differs by the same conductivity type can also be used.

The comprehensive structure of equipment is shown in the view 2 seen from the upper part. This portion P2 of a view 2 is shown in the view 3 in detail with the perspective diagram. This view 3 shows waveguide thin \*\* R in the shape of relief on Waveguide CG, and Waveguide CG has extended on the limit layer C1 and a substrate 10. In accordance with the marginal part, slots S1 and S2 are arranged at the both sides of thin \*\* R, and the pars basilaris ossis occipitalis of these slots is not given to the lower part portion of Waveguide CG. From the edge for a bend, these slots S1 and S2 are estranged from the marginal part of thin \*\* R, therefore the corners Q21 and Q11 of the material of Waveguide CG appear. therefore, these alienation -- the slots S1 and S2 in portions E21 and E11 have a small longitudinal direction size rather than it can set to the field for a bend

P1 portion of the equipment of a view 2 is shown in the view 4 in detail with the perspective diagram. It is shown in this view 4 at the same element as a view 3.

in order to understand the wave propagation phenomenon in a waveguide good -- the -- the flat surfaces AA and BB of the equipment of a view 4 and the cross section on CC are shown in a 5a-5c view, respectively

the -- 5a view is equivalent to the cross section AA which passes along a flat surface perpendicular to the light guide in a part for a bay

The slot is not established in this field. Layer CG has thickness  $eG$ . Thin \*\* R had the longitudinal direction size WG, and only height  $h$  stands straight. The limit layer C1 has the refractive index  $n1$  smaller than the refractive index  $nG$  of Waveguide CG.

the -- 5c view is equivalent to the cross section CC which passes along a flat surface perpendicular to a light guide in the starting position of a curve field Slots S1 and S2 \*\*\*\*\* to the extension wire of the marginal part of waveguide thin \*\* R. The depth of the slots S1 and S2 to the top level of a waveguide is P. The width of face of the slot in the both sides of thin \*\* R is WS.

the [ whose cross section of this beam it appears in compressing a beam enough, these slots are in it by this etching, without changing the energy spread although it does not continue and \*\*\*\*\* in the whole thickness of a waveguide, and is this cross section in this case ] -- the gestalt shown in 5c view with an isoenergetic curve is taken

the -- 5b view is equivalent to the cross section BB which passes along a flat surface perpendicular to a light guide in the field between a cross section AA and a cross section CC

The portions E12 and E22 of slots S1 and S2 show the compression of a beam it is made to move from the gestalt which shows the cross section of a beam with the isoenergetic curve of the 5th the a view to the gestalt shown by the isoenergetic line of the 5th the c view.

Etching depth P of portions E12 and E22 is the same as the etching depth of slots S1 and S2. The length of portions E12, E22, E11, and E21 is l.

Example II: The 6th and 7 views show the 2nd example of this invention.

This light-guide structure is the hetero structure which can carry out \*\*\*\*\* composition of light-gage waveguide thin \*\* R of the same material formed in the front face of the limit layer C1 of a low refractive index with which it consists of InP on the half-insulating substrate 10 which consists of ImP, the waveguide CG of the slightly big refractive index which consists of GaInAsP and the new limit layer C2, and this limit layer C2.

Other III-V group material can be used for forming the waveguide of three components which have a band gap suitable for penetrating this double hetero structure, for example, a substrate, the limit layer of 2 component material, a desired refractive index, and the radiation to be used, or 4 component material.

A view 6 is a perspective diagram of the portion P1 of a view 2.

the -- a 7a-7c view is a cross section which made the cross section AA [ of a view 6 ], BB, and CC line top, respectively The 2nd limit layer C2 which has the very thin thickness  $e3$  improves a performance slightly compared with the equipment of \*\* which requires the technical process of the addition which forms this layer, and the example I which should be made to a balance.

Other portions of this equipment are almost the same as Example I.

In order to carry out this invention, the manufacture method advantageous to below is explained.

Actually, since integrating the equipment which comes out very only and has a certain light guide in a semiconductor material has loss by part for a bend especially with small radius of curvature, although the purpose of this invention is highly efficient, and it is necessary to take this manufacture method into consideration especially to this purpose, equipment is conjointly realized with formation of other integration elements.

The manufacture method by the manufacture method this invention is equipped with the process which forms the pad light guide which has waveguide thin \*\* and at least one bend with small radius of curvature, and the process which forms the slot which restricts light so that light may be guided along with the axis of waveguide thin \*\* in the part for an above-mentioned bend (regulation).

This method is performed at three sequential processes, is a different kind to the last process, namely, needs two masks of a different material which performs selective-etching processing.

A: At this 1st process, the 1st \*\* forms the structure of a juxtaposition layer and forms what has arranged the layer of a slightly high refractive index, and the structure of having the top layer of a low refractive index according to a case, on the equipment by these this inventions, i.e., at least one layer of a low refractive index, (the 9th a - 9c view).

Therefore, in order to acquire the gay structure of Example I, a substrate 10 is formed by carrying out slice cutting from the fixed block of InP of half-insulation first obtained by the crystal pull-up by the

Czochralski method which used for example, liquid encapsulation (encapsulation) (the refer to 9b view). Next, the n+ type InP layer 11 is formed by epitaxial method like MOVPE or VPE. This layer 11 is n which were obtained by doping S+ ion by the concentration of  $4.10^{18}/\text{cm}^3$ , and did not carry out but obtained by carrying out intentional doping to this layer. - The InP layer 12 of type is covered (the refer to 9b view).

Criticality-like [ the thickness of a layer 11 ]. For example, it is  $e_1=3\text{micrometer}$ . This layer 11 is used as a limit layer C1. As for the thickness of a layer 12, being referred to as 3 micrometers is desirable. Since the conductivity type is n-, this layer 12 has a slightly bigger refractive index than the refractive index of a layer 11, therefore this layer 12 carries out the operation which forms the waveguide CG of thickness  $e_G$ , and thin \*\* R of thickness h in fact. According to the method of this invention, thin \*\* R with a waveguide [ CG ] of a thickness  $e_G=2.5\text{micrometer}$  and a height of  $h^{**}0.5\text{ micrometers}$  is obtained from the layer 12 with a thickness of 3 micrometers.

Generally  $1.5 < e_G < 2.5\text{micrometer}$   $0.5 < h < 0.75\text{micrometers}$   $WG^{**}4\text{micrometer}$  is obtained from the layer 12 with a thickness of 2-3 micrometers.

At this example, it is n. - The material InP of type penetrates the radiation which has the wavelength of  $\lambda = 1.3\text{ micrometers}$ , and  $\lambda = 1.55\text{ micrometers}$ .

The substrate 10 of n+ conductivity type is used in the modification of the gay structure of Example I. In this case, this substrate 10 carries out the operation which restricts light (regulation), when forming the epitaxial layer 12 of n-conductivity type in the front face of this substrate directly (the refer to 9a view), as mentioned above.

In order to acquire the double hetero structure of Example II, a substrate 10 is formed by the same method as having used in the Example I at first first.

Next, also in this case, by the MOVPE or VPE type epitaxial method, it carries out by not performing intentional doping which constitutes the limit layer C1, and the layer 21 of InP is formed. And it can be made into about  $e_1=3\text{micrometer}$ . [ the thickness of this layer 21 ]

Next, the epitaxial layer 22 of GaInAsP is formed in the front face of this layer 21. It is desirable to set thickness of this layer 22 to 1.5-2.5 micrometers (the refer to 9c view).

This 4 component layer 22 is used as a waveguide CG of thickness  $e_G$  in fact.

In this example, 4 component material GaInAsP penetrates the wavelength of  $\lambda = 1.3\text{ micrometers}$  or the  $\lambda = 1.55\text{-micrometer}$  radiation actually used for the purpose of electrical communication.

Finally, 2 new component layers 23 of InP are formed in the front face of 4 component layers 22 (the refer to 9c view). As for the thickness of this layer 23, being referred to as 1 micrometer is desirable. In this layer 23, a height of  $h^{**}0.5\text{ micrometers}$  and  $WG^{**}4\text{micrometer}$  thin \*\* R are formed like Example I. In this case, the thickness of the layer 23 which remains in the front face of a layer 22 except thin \*\* R is set to 0.25-0.5 micrometers according to height h ( $0.5 < h < 0.75\text{ micrometers}$ ).

(Low refractive index) The difference of the refractive index between 2 component material and 4 component material restricts light into Layer CG (22).

B: If it finishes forming one side or another side of structure which the flat epitaxial layer mentioned above the 2nd process, the 2nd process by this invention will be started. This processing is shown in the 10th and 11 view to the structure of Examples I and II, respectively. At this 2nd process, thin \*\* R of the letter of relief is formed on the top layer 12 of a semiconductor material, or 13.

For this purpose, the mask systems M1 and M2 are formed at first first. This system can be obtained by the layer 31 of dielectric materials like SiO<sub>2</sub> into which thickness is 500-700nm and turned densely [ high ] by sintering at 420 degrees C for 30 minutes. Next, in this silica layer 31, thickness covers the photoresist layer 32 which is 0.7-1 micrometer, and sinters this for 30 minutes at 90 degrees C at first first (refer to the 10a and 11a view). A mask M2 is left and removed on the front face of the field in which this layer 32 was formed to thin \*\* R by an insulation and decomposition. Next, equipment is gradually made into the temperature of 180 degrees C, and the photoresist layer M2 is stiffened (refer to the 10b and 11b view).

If the top side of semiconductor structure is acquired, gas like for example, the CH<sub>4</sub>/H<sub>2</sub> mixture of gas will perform reactive-ion-etching processing to the circumference of the mask systems M1 and M2. It is

known from the paper written by Mr. NIGEBURUGU (U. Niggebr\*\*gge) etc. to use this mixture of gas for \*\*\*\*\*ing the III-V group compound containing Element In at the 367-372nd page of the reference "Institute Phys.Compt.Serv.No.79, Chapter6" of the international symposium of the compound relevant to GaAs and this which were held in Japan in 1985.

The mask system mentioned above is chosen in order to enable it to use other gas, especially chlorination compounds during etching processing of a semiconductor material.

The etching depth of the request in semiconductor structure is set to height [ of thin \*\* R ] h. Therefore, this etching processing is performed according to the structure in the layer 12 or layer 23 which consists of InP material in the two examples mentioned above.

Control of the etching depth can be performed by the real time using the method indicated by the France country patent application No. 8707796 specification (refer to the 10thd and 11d view).

Thus, thin \*\* R of formed height h is covered with the mask M1 of a silica (SiO<sub>2</sub>), and the mask M2 of a photoresist, and starts the 3rd process of the method by this invention here.

C: In order to perform this 3rd process in which the 3rd process width of face WS forms the slots S1 and S2 which are 1-4 micrometers along the edge of thin \*\* R for a bend for the bend of a light guide (i.e., a light guide), form the photoresist layer 33 at first first. This photoresist layer covers the thickness of 2-4 micrometers, and covers the whole assembly of equipment.

Next, the aperture which is in agreement with the front face of the slots S1 and S2 which should be formed in this photoresist layer 33 by an insulation and decomposition is opened (refer to the 10e and 11e view), and this forms a mask M3.

8a view shows the specific arrangement of a mask M3 to the masks M1 and M2 on which it was superimposed from the upper part. the -- on this mask M3 two apertures O1 and O2 which are in agreement with the slots S1 and S2 which should be formed are opened -- \*\*\*\* -- it takes care that a mask M1, the aperture O1 on M2, and the distance d between O2 become smaller than the size WG of thin \*\* R (namely, masks M1 and M2) The edge of the slot which is most distant from thin \*\* R by this is restricted by the mask M3, and the edge of the slot near thin \*\* R is restricted by the superposition masks M1 and M2.

the -- especially advantageous arrangement of a mask M3 is shown from the upper part, and apertures O1 and O2 connect 8b view on M1 and M2 in this case, and it is each edge which forms the portions E11, E12, E21, and E22 of slots S1 and S2, and forms only one aperture of next form As for the size l of these portions E11, E12, E21, and E22 ( view 2 ), it is desirable to be referred to as l\*\*50 micrometers. these states -- the -- as shown in the 10e of 8a view which is each a cross section on flat-surface I-I and II-II, 11e view and the 10th g, and 11g view, the edge of the slots S1 and S2 most distant from thin \*\* R is restricted by the mask M3, and the edge near thin \*\* R is restricted by masks M1 and M2

By the apertures O1 and O2 of the form mentioned above, material 12 or the layer CG of 22

\*\*\*\*\*s the layer 12 of a semiconductor material, i.e., the layer in the case of the gay structure of Example I, and the layers 23 and 22 in the case of the hetero structure of Example II until only slight thickness with less the total thickness than 20% is corroded. Etching covering depth [ 5 - 16% of ] P of the thickness of the whole is desirable. For example, when the thickness eG of the whole layer 22 is 1.5 micrometers, depth-of-flute P in this layer 22 can be chosen as about 0.2 micrometers.

As mentioned above by the gas CH<sub>4</sub>/H<sub>2</sub> same under the same conditions, a layer 12, or 23 and 22 \*\*\*\*\* by reactive ion etching.

It should be cautious of performing selection of the material which forms two required mask systems when realizing equipment so that masks M1 and M2 may not be influenced during formation of a mask M3. While also being able to use other materials for realizing these two mask systems and forming a mask system by such material in this case, the mask formed of this does not deform but it is contingent [ on not \*\*\*\*\*ing by the same gas as having used for \*\*\*\*\*ing especially semiconductor structure ].

The 10thf and 10h view show the result of the etching processing in the aperture O1 which looked at the structure of Example I by cross-section I-I and II-II of an octavus a view, and O2, and the 11thf and 11h view show the same result seen in the same cross section as the above to the structure of Example II.



Especially the relative configuration of the mask shown especially in an octavus b view is advantageous to an octavus a view. Actually, for the fact that the marginal part of a slot is restricted by masks M1 and M2 along with thin \*\* R, at the 2nd process, etching processing of the slot in alignment with thin \*\* R in the 3rd process aligns completely with the etching processing which forms thin \*\* R, and is performed.

Although mask arrangement of an octavus a view is more slightly [ than mask arrangement of an octavus b view ] difficult, the same result as the case where it is an octavus b view is obtained.

According to the method of this invention, a mask can be obtained easily. That is, a mask can be mutually aligned in non-criticality and self-alignment of the edge of a slot can be completely carried out to the edge of thin \*\*. Therefore, the bad influence by the surface roughness of the edge of a light guide serves as the minimum.

The dissolution in an acetone removes the mask M2 (layer 32) of a photoresist at the time of the end of processing, and hydrogen fluoride (HF) removes the mask M1 (layer 31) of a silica. An acetone also removes the mask M3 of a photoresist.

It should be cautious of it not being absolutely unescapable to form a slot in the crevice of the bend of a light guide. However, by forming this slot, execution of manufacture is made easy, a performance is raised and a limit of the light into a light guide is also improved.

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[Translation done.]

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**TECHNICAL FIELD**

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**(Field of the Invention)**

this invention is a semiconductor device equipped with the integration light guide which has one bay and one bend at least, and the aforementioned light guide has a means to restrict light during a guide by the part for an aforementioned bend, and it relates to the semiconductor device concerned which includes the slot prepared along the edge of a light guide in the aforementioned field for a bend in these meanses.

this invention relates to the method of manufacturing still such a semiconductor device.

this invention is equipped with the light guide which has various curvatures, and is used for manufacture of the Mach-TSUENDA (Mach-Zehnder) modulator in which each light guide has a part for a part for a bay, and a bend one by one, or integration optical equipment like an optical switch.

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## PRIOR ART

(Prior art)

It is known from the paper "Probleme der Topographie Integrierter Schaltungen" written by [ of a book "2213-Frequenz Vol.35 (1981), September No.9 Berlin-Dentschland" / in the 248th page ] Mr. [ Carl Heinz TEUGEN (Karl-Heinz TIETGEN) ] to manufacture the planar light guide which has a part for a bend.

\*\*\*\*\* composition of this planar light guide is carried out in thin \*\* which has an only bigger refractive index than the refractive index of a substrate, and this thin \*\* has been obtained by pouring in titanium into the substrate of  $\text{LiNbO}_3$ , therefore this thin \*\* is in one level which is in agreement with the bottom flat side of a substrate. In such a light guide embedded completely, loss always increases.

In order to reduce loss by the direction dispersion of a path by part for the bend of a light guide, in the above-mentioned paper, forming a slot, for example by etching, embedding in the same height as a part for this bend with radius of curvature with this bigger slot than the part for an aforementioned bend, and following the edge of a light guide correctly is proposed. The slot by this etching enlarges a difference of the refractive index between the atmosphere which is in the exterior of a light guide by the edge side of the light guide of the direction which has the radius of curvature of the larger one, and this light guide.

The radius of curvature of about 0.5mm can be obtained by this method by this paper, and it is made for this not to exceed 3dB for loss.

When such a curved light guide is manufactured, loss arises by dispersion by the edge of a light guide being uneven to an external atmosphere, and it is also indicated by this paper that these losses need to take into consideration the problem relevant to this, for example, reflection, the direction radiation of a path, and mode transformation if the difference of a refractive index becomes large.

In order to make these problems decrease, the light guide which the slot formed of etching has a part for the bottom which inclines slightly and goes up towards the top side of a substrate at the edge of this slot that is in agreement with the start edge of a portion and termination to which the light guide curved, therefore was embedded is regulated by only the substrate of the low refractive index in a part for a bay in the longitudinal direction.

On the other hand, the optical loss by the radiation in the curved light guide is taken into consideration and explained by the reference of "Marcatili and Miller" in "Bell Syst. Techn. 48 and 2161 (1969)."

If the wave of light reaches a part for the bend of a light guide, it is necessary to fit this wave to a part for this bend. A part of energy transmitted for this purpose is changed into a radiation mode. Therefore, energy is emitted to a waveguide side in distribution.

These losses by radiation are based on the fact that it is necessary to move electromagnetic field at a speed quicker than the speed of the light in atmosphere, in order to obtain the same phase velocity as the exterior by part for a bend. While maintaining the wave front, in order to actually move according to a wave front with a fixed angular velocity, it is necessary to proportion the phase velocity of a tangential direction in the distance between the point taken into consideration and the center of curvature of a light guide. If a certain distance D measured from the outside edge of thin \*\* which constitutes a light guide

is exceeded, it will become later than the phase velocity needed for velocity of propagation maintaining the wave front. Therefore, from this distance, the mode will not be able to be spread any longer, but light will be emitted into the substrate located in the height of a curve.

The conversion to the radiation mode of a trapped mode is very disadvantageous for these monochrome mode light guides, when it has the radius of curvature of length with an inadequate monochrome mode light guide.

The formula of a book "Topics in Applied Physics-Vol. 17" which is indicated by the page [ 133rd ] chapter "Integrated Optics" and was established by Mr. mull KATIRI (Marcatili) has given the criticality-radius of curvature  $r$  more as a function of the longitudinal direction limit distance  $D_{\lambda}$  in the mode, i.e., the wavelength used for accuracy as a function of the longitudinal direction range of disappearance of a wave.

Radiation loss cannot be disregarded any longer, when the radius of curvature of a light guide satisfies the following inequalities.

$r < 24\pi D_{\lambda}^2 / \lambda^2$  -- the radius of curvature of a light guide can be made small, without according to this formula, the more increasing the loss produced in the direction of the exterior of a curve, the more longitudinal direction limit distance increases

In the case of a monochrome mode light guide, it is drawn from this formula that a criticality-radius is about 10mm. Consequently, when radius of curvature is smaller than 20mm, the loss by radiation changes good and begins to become large.

According to this formula, it is drawn that it is necessary to increase the longitudinal direction limit distance in the position level of the bend of a light guide, and this is completely in agreement with the indication in the book indicated first.

However, according to the book indicated to the beginning which shows the conventional technology, this problem is difficult to solve to a monochrome mode light guide for the fact of increasing as soon as the difference of the refractive index of loss by dispersion and the atmosphere comparatively for a limit of mode transformation becomes large.

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**TECHNICAL PROBLEM**

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**(Object of the Invention)**

Therefore, it has a part for the bend of radius of curvature smaller than 500 micrometers typically, and a technical problem has loss in the thing more remarkable [ than the radius of curvature in the book mentioned above ] and small for which a very small integration light guide smaller than especially 1 dB/cm is manufactured in the both sides for a part for a bend, and a bay.

Without making dispersion or loss by mode transformation increase, these technical problems are solved by means of this invention to restrict a part for the bend of a light guide so that radiation loss may be oppressed, and they apply these meanses to thin \*\*\*\*\* structure with very less loss in itself than known completeness pad type light-guide structure from the former further.

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MEANS

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(The means for solving a technical problem)

this invention is a semiconductor device equipped with the integration light guide which has one bay and one bend at least. In the semiconductor device concerned which the aforementioned light guide has a means to restrict light into a light guide by the part for an aforementioned bend, and includes the slot prepared along the marginal part of a light guide in the aforementioned field for a bend in these meanses The aforementioned means also contains the waveguide structure which has further a waveguide and thin \*\* of the letter of relief which determines the optical path to which it projects from this waveguide and light follows the inside of this waveguide. The aforementioned means contains the slot structure further and the depth of this slot structure is fixed. The center section of this slot structure follows the marginal part of above thin \*\* correctly by the part for an aforementioned bend. The edge of this slot structure is estranged from the marginal part of above thin \*\* at the aforementioned start edge and aforementioned end edge for a bend, and it is characterized by locating the pars basilaris ossis occipitalis of this slot structure in this waveguide in the level position which does not reach the bottom portion of the aforementioned waveguide.

It explains per drawing below.

the -- when 1a view has a certain distance D measured from the outside convex edge of this light guide in curved light-guide (waveguide) G which has radius of curvature r and this distance D exceeds this distance, it is the distance D which becomes later than a phase velocity required for velocity of propagation to maintain the pars basilaris ossis occipitalis (slash field) of a wave Therefore, from this distance, light will be emitted into a substrate. this -- the -- it is shown in 1b view the [ this ] -- 1b view shows the optical path of the light beam in curved light-guide G which has not established the limit (regulation -- namely, -- shutting up) means by this invention from the upper part It progresses straightly, especially it is divided, therefore, as for the course of an optical path, light shows [ \*\*\*\* in a substrate 10 in all the energy of a trapped mode ] that one main lobe and some minor lobes are formed. the -- the zone which shows the zone shown in 1b view with a dense point by \*\*\*\*\* to a high energy corresponds to low energy Light progresses in the direction of an arrow. the -- if 1b view exceeds a part for the bend of a light guide, in light-guide G shown by the dotted line, it is already shown that energy does not remain

on the other hand -- the -- 1c view shows the optical path of the light beam in curve light-guide G which established the limit means by this invention from the upper part Even if all the energy of a trapped mode exceeds a part for the bend of a light guide, actually remaining in the light guide is shown. Light is spread in the direction of an arrow.

However, when applying the conventional technology which forms a slot by etching along the marginal part of a light guide in the height, a light guide serves as a multimode from a horizontal viewpoint, and it is necessary to make it the difference of the effective refractive index between a waveguide field and the limit field of the contiguity not exceed the order of  $10^{-2}$ . Furthermore, loss by distribution is introduced for the diffraction you are made to produce by the irregularity of the side. According to this invention, the problem mentioned above with the equipment seen and shown in a view 2 from the upper part is

solved.

This equipment has light-guide G to which the front face was restricted by thin \*\* R which has at least one bend which has the average radius  $r$ , and bay. Furthermore, this equipment has the means which maintains the path of a light wave by light-guide G.

The slots S1 and S2 prepared along the marginal part of this light guide by the bend of a light guide are included in these means. According to this invention, these depth of flute presupposes that it is fixed to other datum level, for example, a substrate, as opposed to the top side of this equipment. \*\* which has the longitudinal direction size WS with these slots fixed in the bend of a light guide, The longitudinal direction size of the edges E11 and E12 to a slot S1 and the edges E21 and E22 to a slot S2 is gradually decreased as it approaches the edge of a slot. The radial-border section of a slot is kept parallel to the marginal part of a light guide, and the marginal part of the slot of the direction near the marginal part of a light guide leaves the strips Q11 and Q21 which form the corner which is made to dissociate from the marginal part of a light guide, and has an angle  $\alpha$  among these, and Q12 and Q22. Edges E11, E21, E12, and E22 are made to extend on both sides of the edge of the bend of a light guide at length  $l$ .

these meanses -- the perspective diagram of the 3rd and 4 view -- or as shown in the cross section of the 5a, 5b, and 5c view, \*\*\*\*\* composition of at least two layers C1 and CG is carried out, and the light guide also includes the fact that thin \*\* R is formed in relief on Layer CG

A layer C1 is a limit layer which has a low refractive index from the layer CG which covers this layer. Layer CG is a waveguide, i.e., the layer which a wave spreads. Thin \*\* R formed in the front face of this waveguide restricts the optical path which a wave follows in a waveguide.

As for this thin \*\* R, it is desirable to make it larger than height  $h$  which chose the longitudinal direction size WG on equipment.

Under these conditions, mode transformation can be avoided by two having-two-incomes meanses.

Shortly after a light guide serves as a straight line, a slot depends one having-two-incomes means on the fact of swerving only from an angle  $\alpha$ , from a waveguide field, and the having-two-incomes means of another side is based on the fact of being prepared in the portion P which generally does not exceed 20% of the thickness  $eG$  of Waveguide CG, without continuing and establishing a slot in the whole thickness of Waveguide CG.

This rate is calculated as relation between the refractive index of material, and the wavelength transmitted, in order to restrict a beam by part for the bend of a light guide or to lose mode transformation.

Therefore, the means by this invention, i.e., a means to arrange light-gage waveguide thin \*\* which has a part for a bend on - waveguide, - The slot means established to the marginal part of waveguide thin \*\* in a part for a bend, a means to begin the slot on these from the edge for a bend, and to make only an angle  $\alpha$  estrange from the marginal part of waveguide thin \*\*, By using a means to form the slot on these in the depth shallower than the thickness of a waveguide, - Loss of a beam The fact that there is no lateral dispersion is benefited very small in a part for a bay. to b \*\*\*\*\* this beam Horizontal combination can be easily carried out now at other beams with which a wave spreads the inside of the same waveguide. c) In a part for a bend, loss of this beam becomes very small and the radius of curvature for this bend can do it very small at about 50 micrometers. d) Since it does not reach the pars basilaris ossis occipitalis of a waveguide, a slot can avoid any mode transformation, and since it is comparatively shallow, the loss of  $e$  depth of flute resulting from longitudinal direction dispersion by the diffraction on a wall decreases extremely.

Therefore, the performance of the equipment which provided the means by this invention becomes high especially.

Example I: The 3rd, 4, and 5 views show one example of the equipment which has the integration light guide (waveguide) which established the means by this invention.

This light-guide structure is arranged on  $n^+$  the limit layer C1 which has the low refractive index which consists of InP of type and this layer C1 which can be formed for example, on the half-insulating substrate 10 of InP. - It is gay structure with thin \*\* R of the thin meat which consists of the same material as the waveguide CG which consists of InP of type, and this layer CG.

In order to acquire the above-mentioned gay structure, other 2 component material of the III-V group from whom specific resistance differs by the same conductivity type can also be used.

The comprehensive structure of equipment is shown in the view 2 seen from the upper part. This portion P2 of a view 2 is shown in the view 3 in detail with the perspective diagram. This view 3 shows waveguide thin \*\* R in the shape of relief on Waveguide CG, and Waveguide CG has extended on the limit layer C1 and a substrate 10. In accordance with the marginal part, slots S1 and S2 are arranged at the both sides of thin \*\* R, and the pars basilaris ossis occipitalis of these slots is not given to the lower part portion of Waveguide CG. From the edge for a bend, these slots S1 and S2 are estranged from the marginal part of thin \*\* R, therefore the corners Q21 and Q11 of the material of Waveguide CG appear. therefore, these alienation -- the slots S1 and S2 in portions E21 and E11 have a small longitudinal direction size rather than it can set to the field for a bend

P1 portion of the equipment of a view 2 is shown in the view 4 in detail with the perspective diagram. It is shown in this view 4 at the same element as a view 3.

in order to understand the wave propagation phenomenon in a waveguide good -- the -- the flat surfaces AA and BB of the equipment of a view 4 and the cross section on CC are shown in a 5a-5c view, respectively

the -- 5a view is equivalent to the cross section AA which passes along a flat surface perpendicular to the light guide in a part for a bay

The slot is not established in this field. Layer CG has thickness eG. Thin \*\* R had the longitudinal direction size WG, and only height h stands straight. The limit layer C1 has the refractive index n1 smaller than the refractive index nG of Waveguide CG.

the -- 5c view is equivalent to the cross section CC which passes along a flat surface perpendicular to a light guide in the starting position of a curve field Slots S1 and S2 \*\*\*\*\* to the extension wire of the marginal part of waveguide thin \*\* R. The depth of the slots S1 and S2 to the top level of a waveguide is P. The width of face of the slot in the both sides of thin \*\* R is WS.

the [ whose cross section of this beam it appears in compressing a beam enough, these slots are in it by this etching, without changing the energy spread although it does not continue and \*\*\*\*\* in the whole thickness of a waveguide, and is this cross section in this case ] -- the gestalt shown in 5c view with an isoenergetic curve is taken

the -- 5b view is equivalent to the cross section BB which passes along a flat surface perpendicular to a light guide in the field between a cross section AA and a cross section CC

the portions E12 and E22 of slots S1 and S2 -- the cross section of a beam -- the -- the [ from the form shown by energy curves, such as 5a view, ] -- the compression of a beam from which it is made to move to the form shown by energy lines, such as 5c view, is shown

Etching depth P of portions E12 and E22 is the same as the etching depth of slots S1 and S2. The length of portions E12, E22, E11, and E21 is l.

Example II: The 6th and 7 views show the 2nd example of this invention.

This light-guide structure is the hetero structure which can carry out \*\*\*\*\* composition of light-gage waveguide thin \*\* R of the same material formed in the front face of the limit layer C1 of a low refractive index with which it consists of InP on the half-insulating substrate 10 which consists of ImP, the waveguide CG of the slightly big refractive index which consists of GaInAsP and the new limit layer C2, and this limit layer C2.

Other III-V group material can be used for forming the waveguide of three components which have a band gap suitable for penetrating this double hetero structure, for example, a substrate, the limit layer of 2 component material, a desired refractive index, and the radiation to be used, or 4 component material.

A view 6 is a perspective diagram of the portion P1 of a view 2.

the -- a 7a-7c view is a cross section which made the cross section AA [ of a view 6 ], BB, and CC line top, respectively The 2nd limit layer C2 which has the very thin thickness e3 improves a performance slightly compared with the equipment of \*\* which requires the technical process of the addition which forms this layer, and the example I which should be made to a balance.

Other portions of this equipment are almost the same as Example I.



In order to carry out this invention, the manufacture method advantageous to below is explained. Actually, since integrating the equipment which comes out very only and has a certain light guide in a semiconductor material has loss by part for a bend especially with small radius of curvature, although the purpose of this invention is highly efficient, and it is necessary to take this manufacture method into consideration especially to this purpose, equipment is conjointly realized with formation of other integration elements.

The manufacture method by the manufacture method this invention is equipped with the process which forms the pad light guide which has waveguide thin \*\* and at least one bend with small radius of curvature, and the process which forms the slot which restricts light so that light may be guided along with the axis of waveguide thin \*\* in the part for an above-mentioned bend (regulation).

This method is performed at three sequential processes, is a different kind to the last process, namely, needs two masks of a different material which performs selective-etching processing.

A: At this 1st process, the 1st \*\* forms the structure of a juxtaposition layer and forms what has arranged the layer of a slightly high refractive index, and the structure of having the top layer of a low refractive index according to a case, on the equipment by these this inventions, i.e., at least one layer of a low refractive index, (the 9th a - 9c view).

Therefore, in order to acquire the gay structure of Example I, a substrate 10 is formed by carrying out slice cutting from the fixed block of InP of half-insulation first obtained by the crystal pull-up by the Czochralski method which used for example, liquid encapsulation (encapsulation) (the refer to 9b view). Next, the n+ type InP layer 11 is formed by epitaxial method like MOVPE or VPE. This layer 11 is n which were obtained by doping S+ ion by the concentration of  $4.1018\text{-}/\text{cm}^3$ , and did not carry out but obtained by carrying out intentional doping to this layer. - The InP layer 12 of type is covered (the refer to 9b view).

Criticality-like [ the thickness of a layer 11 ]. For example, it is  $e1=3\text{micrometer}$ . This layer 11 is used as a limit layer C1. As for the thickness of a layer 12, being referred to as 3 micrometers is desirable. Since the conductivity type is n-, this layer 12 has a slightly bigger refractive index than the refractive index of a layer 11, therefore this layer 12 carries out the operation which forms the waveguide CG of thickness eG, and thin \*\* R of thickness h in fact. According to the method of this invention, thin \*\* R with a waveguide [ CG ] of a thickness  $eG=2.5\text{micrometer}$  and a height of  $h^{**}0.5\text{micrometers}$  is obtained from the layer 12 with a thickness of 3 micrometers.

Generally  $1.5 < eG < 2.5\text{micrometer}$   $0.5 < h < 0.75\text{micrometers}$  WG\*\*4micrometer is obtained from the layer 12 with a thickness of 2-3 micrometers.

At this example, it is n. - The material InP of type penetrates the radiation which has the wavelength of  $\lambda = 1.3\text{micrometers}$ , and  $\lambda = 1.55\text{micrometers}$ .

The substrate 10 of n+ conductivity type is used in the modification of the gay structure of Example I. In this case, this substrate 10 carries out the operation which restricts light (regulation), when forming the epitaxial layer 12 of n-conductivity type in the front face of this substrate directly (the refer to 9a view), as mentioned above.

In order to acquire the double hetero structure of Example II, a substrate 10 is formed by the same method as having used in the Example I at first first.

Next, also in this case, by the MOVPE or VPE type epitaxial method, it carries out by not performing intentional doping which constitutes the limit layer C1, and the layer 21 of InP is formed. And it can be made into about  $e1=3\text{micrometer}$ . [ the thickness of this layer 21 ]

Next, the epitaxial layer 22 of GaInAsP is formed in the front face of this layer 21. It is desirable to set thickness of this layer 22 to 1.5-2.5 micrometers (the refer to 9c view).

This 4 component layer 22 is used as a waveguide CG of thickness eG in fact.

In this example, 4 component material GaInAsP penetrates the wavelength of  $\lambda = 1.3\text{micrometers}$  or the  $\lambda = 1.55\text{-micrometer}$  radiation actually used for the purpose of electrical communication.

Finally, 2 new component layers 23 of InP are formed in the front face of 4 component layers 22 (the refer to 9c view). As for the thickness of this layer 23, being referred to as 1 micrometer is desirable. In this layer 23, a height of  $h^{**}0.5\text{micrometers}$  and WG\*\*4micrometer thin \*\* R are formed like Example

I. In this case, the thickness of the layer 23 which remains in the front face of a layer 22 except thin \*\* R is set to 0.25-0.5 micrometers according to height  $h$  ( $0.5 < h < 0.75$  micrometers).

(Low refractive index) The difference of the refractive index between 2 component material and 4 component material restricts light into Layer CG (22).

B: If it finishes forming one side or another side of structure which the flat epitaxial layer mentioned above the 2nd process, the 2nd process by this invention will be started. This processing is shown in the 10th and 11 view to the structure of Examples I and II, respectively. At this 2nd process, thin \*\* R of the letter of relief is formed on the top layer 12 of a semiconductor material, or 13.

For this purpose, the mask systems M1 and M2 are formed at first first. This system can be obtained by the layer 31 of dielectric materials like SiO<sub>2</sub> into which thickness is 500-700nm and turned densely [ high ] by sintering at 420 degrees C for 30 minutes. Next, in this silica layer 31, thickness covers the photoresist layer 32 which is 0.7-1 micrometer, and sinters this for 30 minutes at 90 degrees C at first first (refer to the 10a and 11a view). A mask M2 is left and removed on the front face of the field in which this layer 32 was formed to thin \*\* R by an insulation and decomposition. Next, equipment is gradually made into the temperature of 180 degrees C, and the photoresist layer M2 is stiffened (refer to the 10b and 11b view).

If the top side of semiconductor structure is acquired, gas like for example, the CH<sub>4</sub>/H<sub>2</sub> mixture of gas will perform reactive-ion-etching processing to the circumference of the mask systems M1 and M2. It is known from the paper written by Mr. NIGEBURUGU (U. Niggebr\*\*gge) etc. to use this mixture of gas for \*\*\*\*\*ing the III-V group compound containing Element In at the 367-372nd page of the reference "Institute Phys.Compt.Serv.No.79, Chapter6" of the international symposium of the compound relevant to GaAs and this which were held in Japan in 1985.

The mask system mentioned above is chosen in order to enable it to use other gas, especially chlorination compounds during etching processing of a semiconductor material.

The etching depth of the request in semiconductor structure is set to height [ of thin \*\* R ]  $h$ . Therefore, this etching processing is performed according to the structure in the layer 12 or layer 23 which consists of InP material in the two examples mentioned above.

Control of the etching depth can be performed by the real time using the method indicated by the France country patent application No. 8707796 specification (refer to the 10thd and 11d view).

Thus, thin \*\* R of formed height  $h$  is covered with the mask M1 of a silica (SiO<sub>2</sub>), and the mask M2 of a photoresist, and starts the 3rd process of the method by this invention here.

C: In order to perform this 3rd process in which the 3rd process width of face WS forms the slots S1 and S2 which are 1-4 micrometers along the marginal part of thin \*\* R for a bend for the bend of a light guide (i.e., a light guide), form the photoresist layer 33 at first first. This photoresist layer covers the thickness of 2-4 micrometers, and covers the whole assembly of equipment.

Next, the aperture which is in agreement with the front face of the slots S1 and S2 which should be formed in this photoresist layer 33 by an insulation and decomposition is opened (refer to the 10e and 11e view), and this forms a mask M3.

The octavus a view shows the specific arrangement of a mask M3 to the masks M1 and M2 on which it was superimposed from the upper part. on this mask M3 two apertures O1 and O2 which are in agreement with the slots S1 and S2 which should be formed are opened -- \*\*\*\* -- it takes care that a mask M1, the aperture O1 on M2, and the distance  $d$  between O2 become smaller than the size WG of thin \*\* R (namely, masks M1 and M2) The marginal part of the slot which is most distant from thin \*\* R by this is restricted by the mask M3, and the marginal part of the slot near thin \*\* R is restricted by the superposition masks M1 and M2.

Especially advantageous arrangement of a mask M3 is shown from the upper part, and apertures O1 and O2 connect an octavus b view on M1 and M2 in this case, and it is each edge which forms the portions E11, E12, E21, and E22 of slots S1 and S2, and forms only one aperture of next gestalt. As for the size  $l$  of these portions E11, E12, E21, and E22 ( view 2 ), it is desirable to be referred to as  $l^{**50}$  micrometers.

In these state, as shown in the 10e of an octavus a view which is each a cross section on flat-surface I-I

and II-II, 11e view and the 10th g, and 11g view, the marginal part of the slots S1 and S2 most distant from thin \*\* R is restricted by the mask M3, and the marginal part near thin \*\* R is restricted by masks M1 and M2.

By the apertures O1 and O2 of the gestalt mentioned above, material 12 or the layer CG of 22 \*\*\*\*\*s the layer 12 of a semiconductor material, i.e., the layer in the case of the gay structure of Example I, and the layers 23 and 22 in the case of the hetero structure of Example II until only slight thickness with less the total thickness than 20% is corroded. Etching covering depth [ 5 - 16% of ] P of the thickness of the whole is desirable. For example, when the thickness eG of the whole layer 22 is 1.5 micrometers, depth-of-flute P in this layer 22 can be chosen as about 0.2 micrometers.

As mentioned above by the gas CH<sub>4</sub>/H<sub>2</sub> same under the same conditions, a layer 12, or 23 and 22 \*\*\*\*\* by reactive ion etching.

It should be cautious of performing selection of the material which forms two required mask systems when realizing equipment so that masks M1 and M2 may not be influenced during formation of a mask M3. While also being able to use other materials for realizing these two mask systems and forming a mask system by such material in this case, the mask formed of this does not deform but it is contingent [ on not \*\*\*\*\*ing by the same gas as having used for \*\*\*\*\*ing especially semiconductor structure ].

The 10thf and 10h view show the result of the etching processing in the aperture O1 which looked at the structure of Example I by cross-section I-I and II-II of an octavus a view, and O2, and the 11thf and 11h view show the same result seen in the same cross section as the above to the structure of Example II. Especially the relative configuration of the mask shown especially in an octavus b view is advantageous to an octavus a view. Actually, for the fact that the marginal part of a slot is restricted by masks M1 and M2 along with thin \*\* R, at the 2nd process, etching processing of the slot in alignment with thin \*\* R in the 3rd process aligns completely with the etching processing which forms thin \*\* R, and is performed.

Although mask arrangement of an octavus a view is more slightly [ than mask arrangement of an octavus b view ] difficult, the same result as the case where it is an octavus b view is obtained. According to the method of this invention, a mask can be obtained easily. That is, a mask can be mutually aligned in non-criticality and self-alignment of the marginal part of a slot can be completely carried out to the marginal part of thin \*\*. Therefore, the bad influence by the surface roughness of the marginal part of a light guide serves as the minimum.

The dissolution in an acetone removes the mask M2 (layer 32) of a photoresist at the time of the end of processing, and hydrogen fluoride (HF) removes the mask M1 (layer 31) of a silica. An acetone also removes the mask M3 of a photoresist.

It should be cautious of it not being absolutely unescapable to form a slot in the crevice of the bend of a light guide. However, by forming this slot, execution of manufacture is made easy, a performance is raised and a limit of the light into a light guide is also improved.

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[Translation done.]

## \* NOTICES \*

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2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

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DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]

the -- the diagram showing the configuration of the wave in the monochrome mode light guide to which 1a view curved

the -- the diagram which looked at the path of the light beam in the curved light guide which has not established the limit means according [ 1b view ] to this invention from the upper part

the -- the diagram which looked at the path of the light beam in the curved light guide which established the limit means according [ 1c view ] to this invention from the upper part

A view 2 is a diagram showing the means by this invention which restricts light into the curved light guide.

A view 3 is a perspective diagram showing the portion P2 of a view 2 in the 1st example.

A view 4 is a perspective diagram showing the portion P1 of a view 2 in the 1st example.

the -- the cross section 5a-5c showing the portion P1 of a view 4 as a cross section in respect of various

A view 6 is a perspective diagram showing the portion P1 of a view 2 in other examples.

the -- the cross section 7a-7c showing the portion P1 of a view 6 as a cross section in respect of various Octavus a and 8b view are a diagram showing two possible relative configurations of the mask for enforcing the manufacture method of equipment.

the -- the cross section showing the 1st phase of the manufacture method in two examples of the above [ a 9a-9c view ]

the -- the cross section showing the 2nd and 3rd phases of the manufacture method in the 1st example of the above [ 10a-10h view ]

the -- 11a-11h view is a cross section showing the 2nd and 3rd phases of the manufacture method in the 2nd aforementioned example

C -- A light guide, S1, S2 -- Slot

R -- Thin \*\*, CG -- Waveguide

C1, C2 -- Limit layer

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[Translation done.]

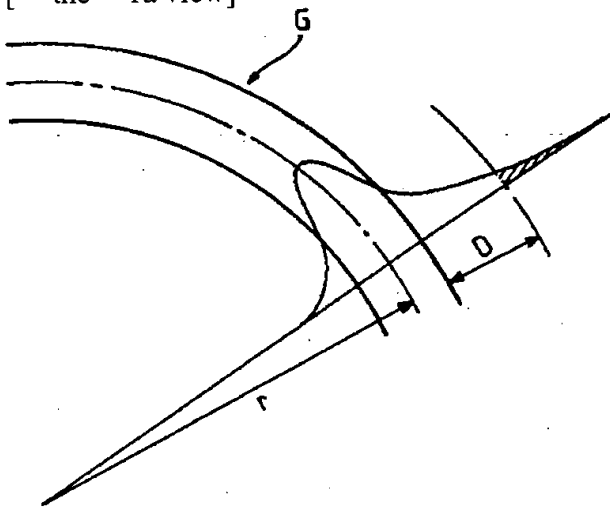
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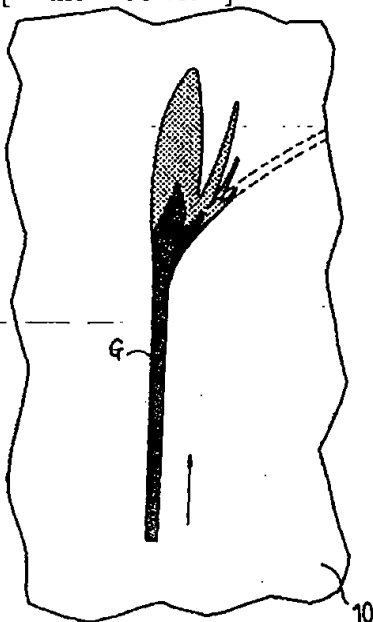
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**DRAWINGS**

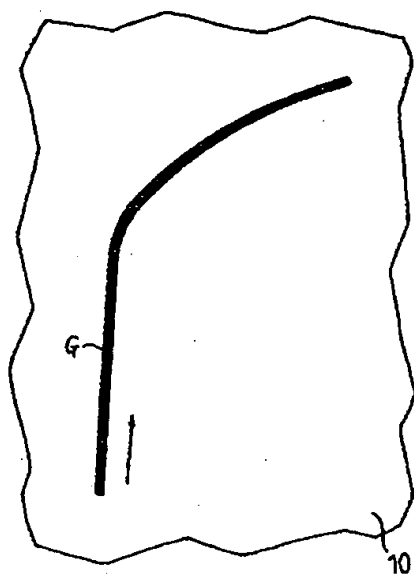
[ -- the -- 1a view]



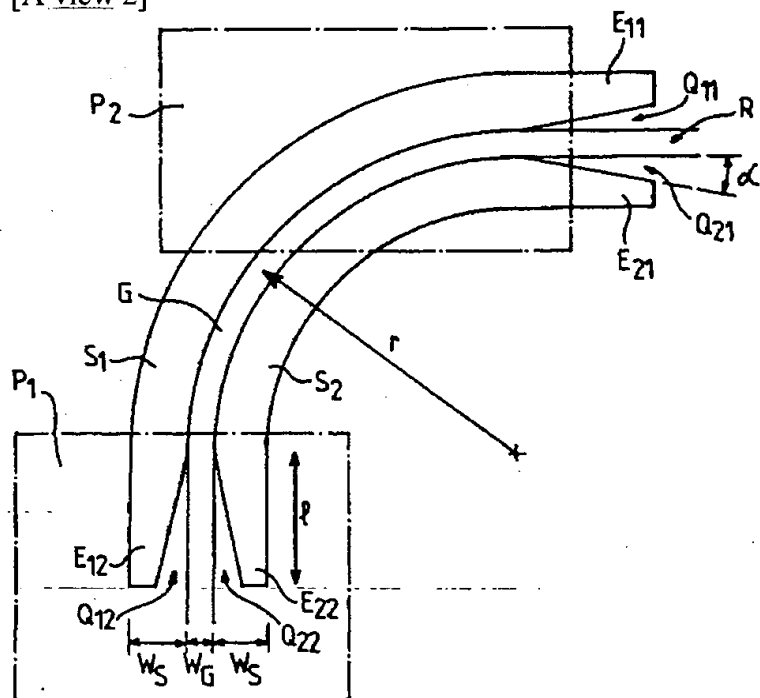
[ -- the -- 1b view]



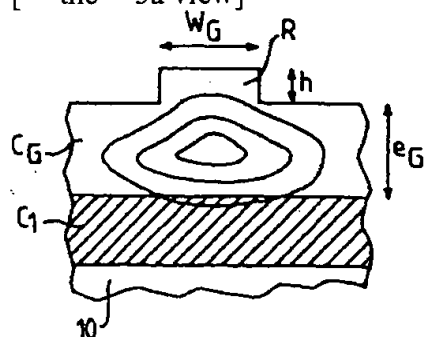
[The 1st C view]



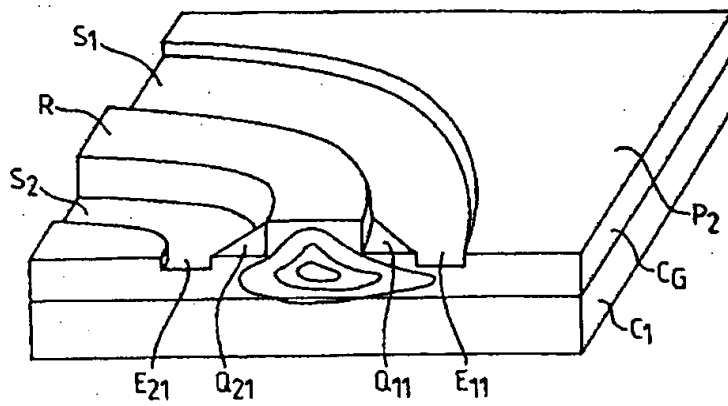
[A view 2]



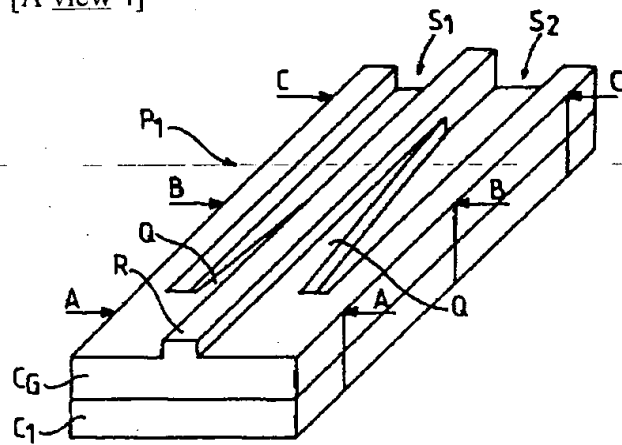
[-- the -- 5a view]



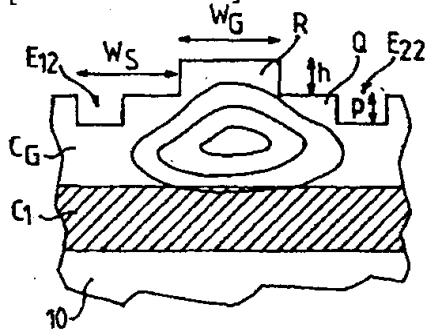
[A view 3]



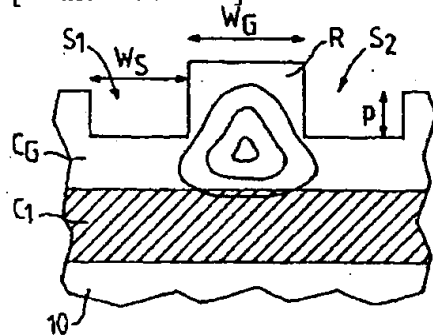
[A view 4]



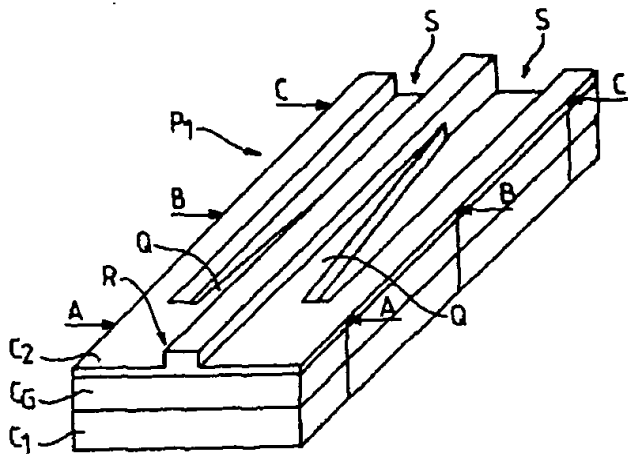
[ -- the -- 5b view]



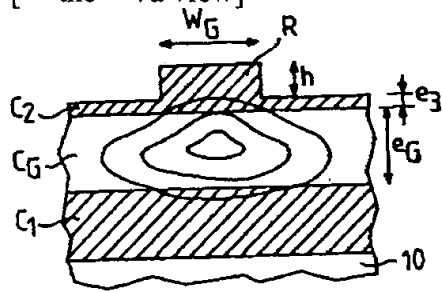
[ -- the -- 5c view]



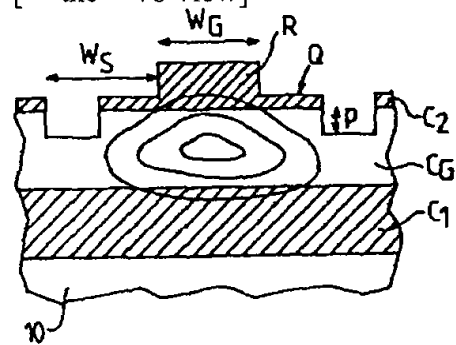
[A view 6]



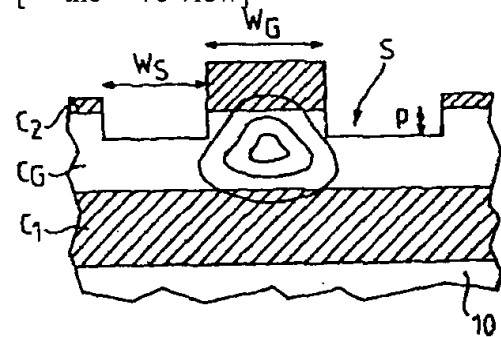
[ -- the -- 7a view]



[ -- the -- 7b view]

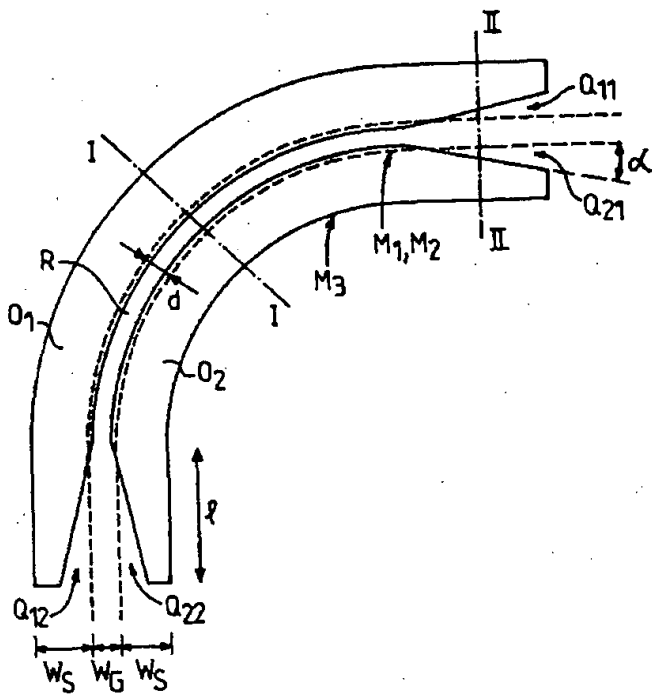


[ -- the -- 7c view]

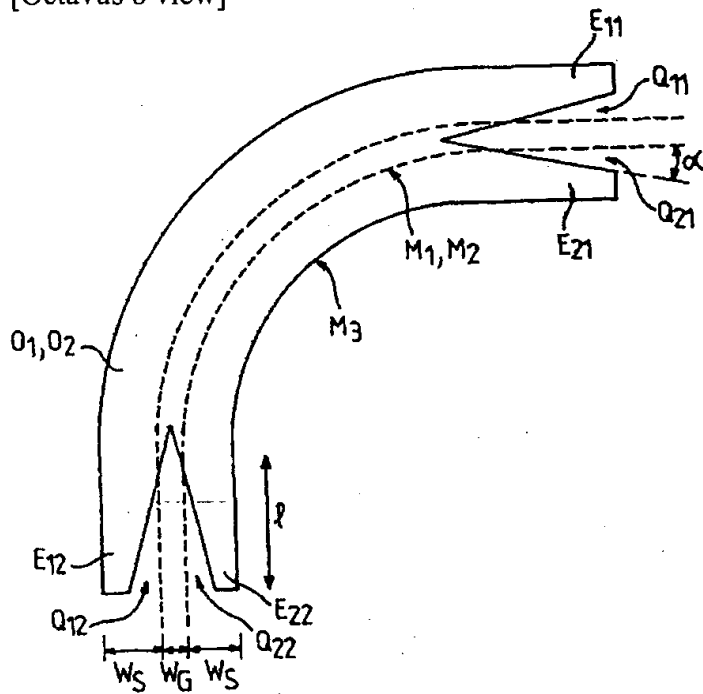


[Octavus a view]

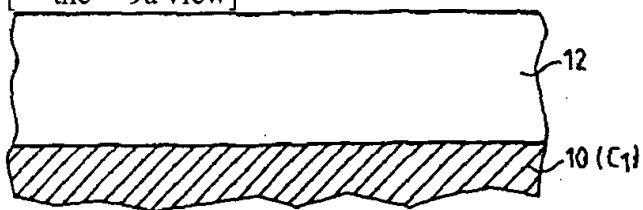




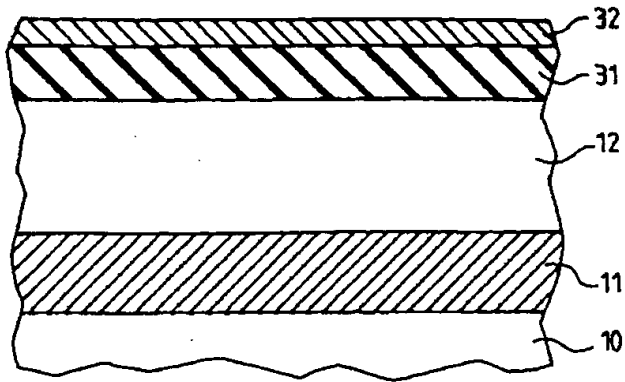
[Octavus b view]



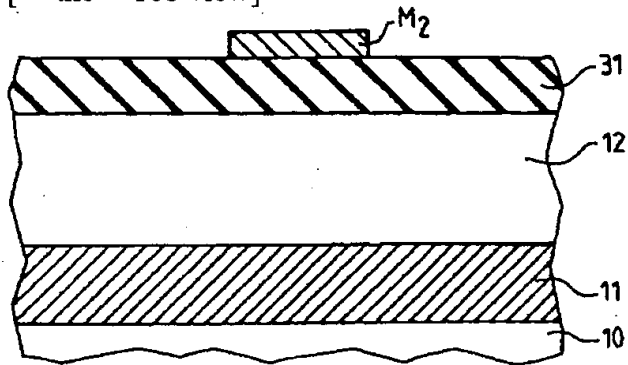
[ -- the -- 9a view]



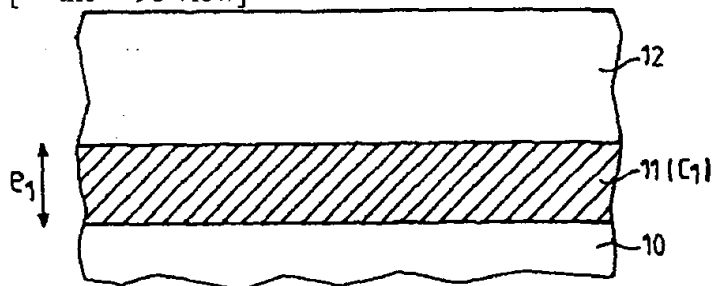
[ -- the -- 10a view]



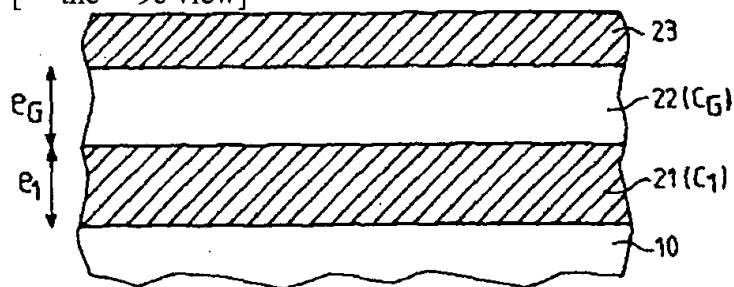
[ -- the -- 10b view]



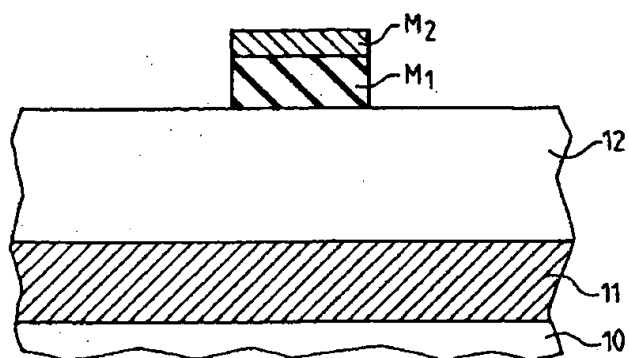
[ -- the -- 9b view]



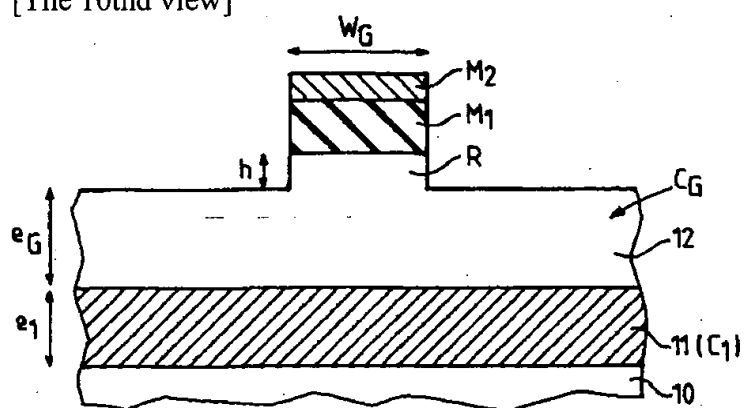
[ -- the -- 9c view]



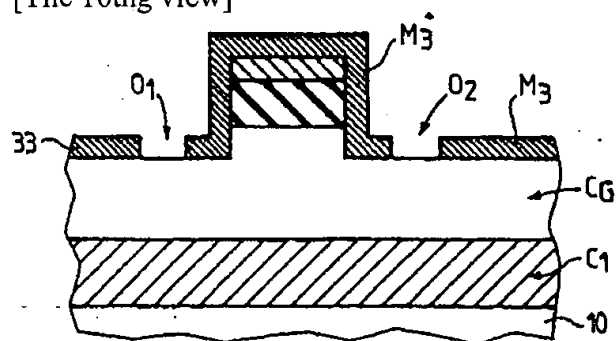
[ -- the -- 10c view]



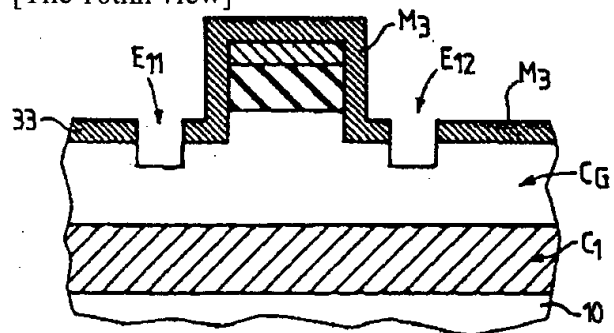
[The 10thd view]



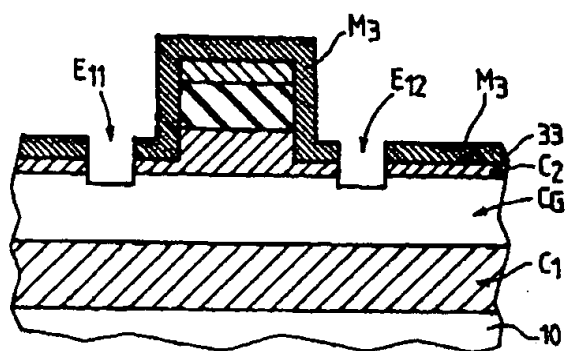
[The 10thg view]



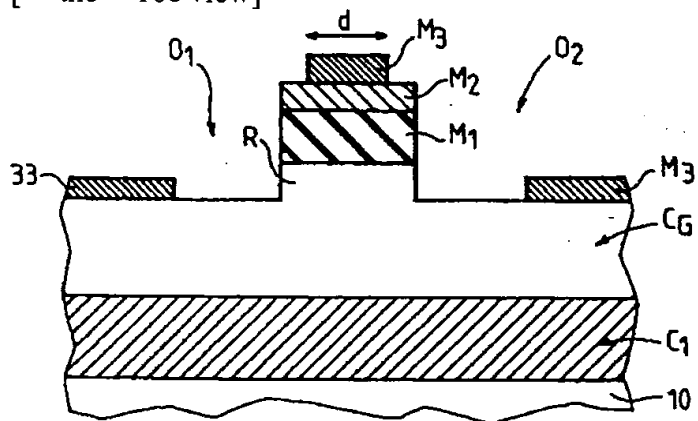
[The 10thh view]



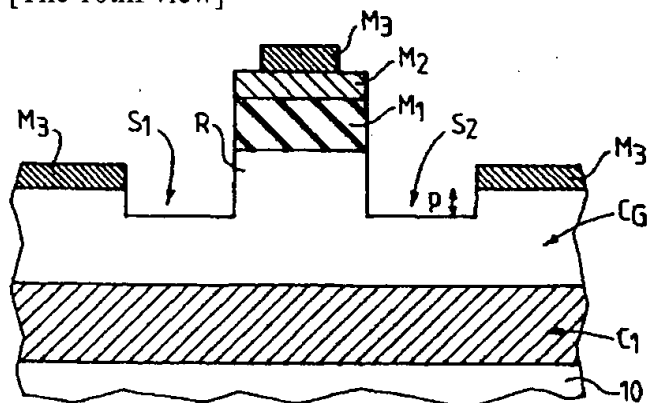
[The 11thh view]



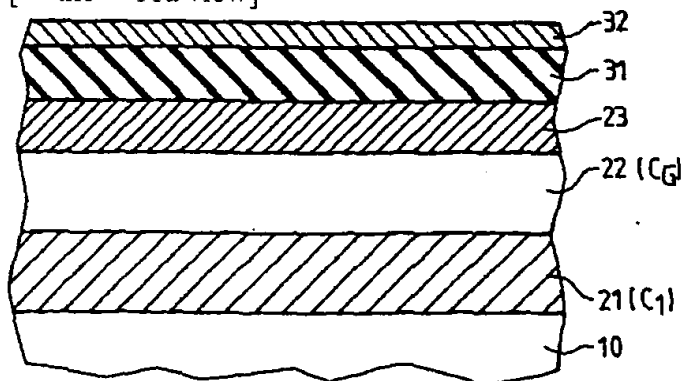
[ -- the -- 10e view]



[The 10thf view]

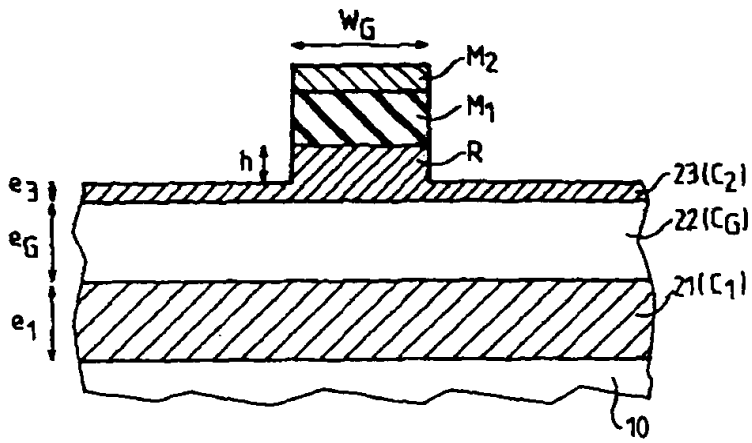


[ -- the -- 11a view]

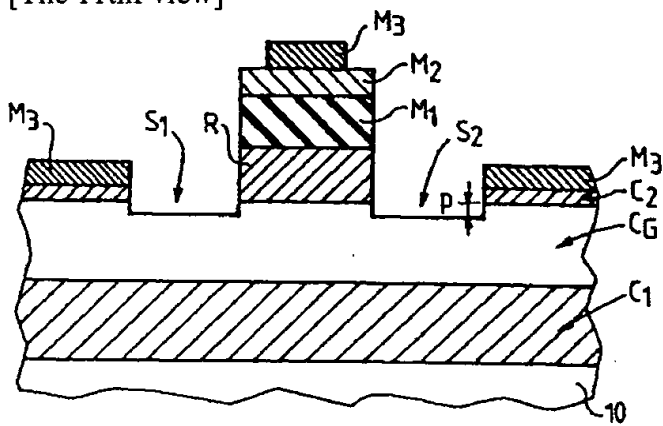


[ -- the -- 11b view]





[The 11th view]



[Translation done.]